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From open packing to negative wound pressure therapy. A critical overview of deep sternal wound infection treatment strategies after cardiac surgery

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Deep sternal wound infection is a challenging aspect of modern cardiac surgery. The considerable mortality rate, devastating morbidity and, negative impact on long-term survival has driven cardiac and plastic surgeons to seek a more advantageous treatment solution. This review summarizes progress in the field of deep sternal wound infection treatment after cardiac surgery. Emphasis is placed on outcomes analysis of contemporary treatment strategy based on negative pressure wound therapy followed by sternotomy wound reconstruction, and its comparison with conventional treatment modalities used afore. Furthermore, complications and drawbacks of treatment strategies are critically evaluated to outline current options for successfully managing this life-threatening complication following cardiac surgery

Key words: sternal wound infection, conventional treatment, pressure wound therapy

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INTRODUCTION

Deep sternal wound infection (DSWI) is a serious complication of cardiac surgery. Even with implementation of modern treatment strategies, in-hospital mortality of DSWI widely ranges between 5.1-19% (ref.[1]). A major factor concerning the care of DSWI's patients is the considerable increase in morbidity linked to prolonged ICU and in-hospital stay and rate of re-interventions. Moreover, development of late complications deteriorates patients' quality of life and requires further in-hospital and out-patient care[2]. The result is a three-fold increase in healthcare costs and a negative impact on long-term survival of patients who have successfully overcome DSWI (ref.[2,3]). Treatment of DSWI has evolved from being based on conventional treatment with closed irrigation or application of muscle or omental flap after sternotomy wound debridement to primary application of negative pressure wound therapy followed by stable sternotomy wound reconstruction[1].

Conventional treatment (CT)

Until the beginning of the 1960s, DSWI patients were treated either conservatively, which included antibiotic treatment and eventually limited drainage, or by open dressing of the exposed sternotomy wound until being closed with granulation tissue (open packing). This resulted in a 50% mortality and devastating morbidity of survivors related to chest wall instability and complicated wound healing[4]. In 1964, Shumacker and Mandelbaum reported their experience with continuous antibiotic irrigation in two patients[5]. The treatment consisted of complete sternotomy revision and removal of osteosynthetic material. After the debridement, the sternotomy wound was irrigated with an antibiotic solution, closed by sternal re-wiring and continuously irrigated through indwelling drains. The original method was subsequently modified in terms of the setting and the number of indwelling drains used for irrigation, the type of antiseptic or antibiotic solution used and the type of sternal re-wiring technique performed[6,7]. Targeted antibiotic therapy was part of the treatment. This strategy of treatment was consequently called closed irrigation and became widely used for DSWI, especially in Europe. The reason behind its popularity lies in its simplicity and direct stabilization of the chest. Reported mortality of closed irrigation ranged between 4.8-28%, nevertheless the treatment was linked to failure in 12.5-48% of cases, which correlates with the type of DSWI according to Oakley and Wright classification[7-10]. Age over 75 (OR 1.01; 1.02-1.18; P=0.01), renal failure (OR 4.8; 1.03-22.32; P=0.04) and MRSA infection (OR 6.8; 1.04-44.48; P=0.05) were identified to be independent predictors of closed irrigation failure[9].

In 1976, Lee successfully used part of the greater omentum to cover an infected sternotomy wound after closed irrigation therapy had failed[11]. After the sternal wound debridement, fixation of the omentum to rest of the skeletal structures was made, followed by soft tissue closure by secondary intention. Omentum was used as the flap due to its high vascularity, which provides its absorptive abilities as well as high local antibiotic availability. Technically, it is possible to use the entire greater omentum on its long vessel pedicle, which allows for filling of deep cavities or covering large superficial defects[12]. Drawbacks of using the omentum include abdominal cavity opening and, furthermore, its edema which may result in delayed primary wound closure or need for dermo-epidermal grafting[13].

At the beginning of the 1980s, several reasons (e.g. negative effects on respiration mechanics, inability to mobilize patients, and increased risk of mediastinal structures injury during re-dressing or coughing) led Jurkiewicz to modify the approach of open packing wound management. He implemented a single-stage procedure which combines extensive debridement of sternotomy wound and its covering by using muscle flap, or alternatively in combination with omental flap[14]. Results of 409 patients with DSWI published over 20 years showed an 8.1% in-hospital mortality and merely 5.1% risk of primary DSWI treatment failure[15]. Transfer of both pectoral muscles was used in 79.4% of cases, whereas the rectus abdominis muscle advancement was utilized in 19.4% of cases. The greater omentum was used in only 2.2% of cases[15]. Afterwards, the treatment strategy was modified by numerous groups, particularly with respect to the debridement extent, the type of flap used and the timing of wound closure. Published mortality of these modifications ranged between 6.4-19% and risk of treatment failure between 4.4-11.2% (ref.[15-17]). Extensive sternal debridement resulted in a lower risk of treatment failure when compared to closed irrigation. Nevertheless, even after successful healing of the sternotomy wound, more than half of the patients complained about chronic pain, increased skin sensitivity as well as rib cage instability. Moreover, a third of patients indicated shoulder weakness in connection with pectoral muscles de-insertion[18]. Usage of the omental flap over the pectoral muscles resulted in lower in-hospital mortality (4.8 vs. 10.5%, $P<0.05$), lower incidence of muscle flap harvest complications (9.5 vs. 27.7%, $P<0.0001$) and shorter in-hospital stay (10.7 vs. 18.8 days, $P<0.05$) (ref.[19,20]). Sepsis (OR 11.2, $P<0.0001$), MOF (OR 9.4, $P=0.001$), ICU length of stay greater than 96 hours (OR 7.58, $P=0.007$) as well as late presentation of DSWI over 20 days (OR 35.5, $P<0.001$) were identified as independent mortality predictors with this treatment[5,21].

At the end of the 1990s, Oakley and Wright published a DSWI classification system for DSWI treatment stratification in the CT era[10]. The authors based it on retrospective comparative analyses results of closed irrigation with primary muscle flap covering. These showed comparable mortality results in early DSWI forms with absence of risk factors (class I and II), but with significantly shorter in-ICU stay length and in-hospital stay length in closed irrigation treatment[22,23]. On the other hand, presence of DSWI development risk factors (class III) notably increased risk of closed irrigation failure in comparison to primary muscle flap covering[7,24]. In patients with failure of primary DSWI treatment (class IV) and in late forms of DSWI (>6 weeks, class V), modified open package treatment with delayed reconstruction should be preferred[10]. Nowadays, closed irrigation is used by some centres even for treatment of early DSWI forms possessing no risk factors (class I and II) with satisfactory results[25]. The primary muscle flap covering after extensive debridement, at the present time, was substituted by primary application of negative pressure wound therapy with subsequent sternotomy wound reconstruction.

Negative pressure wound therapy (NPWT)

In 1997, Obdeijn described the first NPWT usage in 3 patients with DSWI. All the patients were extubated and ventilated spontaneously between re-dressing[26]. The first retrospective comparison of NPWT with closed irrigation in a small cohort was published 3 years later. In the NPWT group, a shorter in-hospital stay and decreased primary treatment failure was recorded[27]. A fairly active Lund's group invented a unified NPWT protocol in DSWI and implemented it into practice. Protection of the mediastinal structures was included in the protocol as well[28]. Afterwards, the group also published results of DSWI patients' long-term survival rates that were, in contrast to CT, comparable with survival of patients without sternotomy wound healing disturbances after cardiac surgery[29]. Results of centres, which systematically focus on NPWT, showed 1.1-5.4% 30-day, 8-15% 1-year mortality and 2-8% risk of primary treatment failure in patients with DSWI (ref.[29,30]). Average duration of NPWT ranged between 8-12 days with 4 to 6 surgical revisions followed by NPWT application[29,30]. There are some modifications of the NPWT protocol among centres which differ in type of non-adhesive coverage used to protect mediastinum and, furthermore, differ in timing of sternotomy wound closure. CRP level drop (<50 mg/L) together with satisfactory local finding are accepted triggers of sternotomy wound closure[31]. Obesity, renal failure, sepsis and delayed surgical revision were determined to be independent predictors of negative results of NPWT (ref.[32,33]).

Antibiotic treatment

Antibiotic therapy is an integral part of the treatment strategy, including a focus the on type of agent, its detected sensitivity and pharmacokinetic properties. Although, we know the differences in penetration of various antibiotics, hypo-vital and necrotic tissues, predominantly in skeleton, remain a huge therapeutic problem[34]. A biofilm production by some microbial agents is a recent topic of interest as such agents are basically unaffected by systemic administration of antibiotics[35]. After the sternotomy reconstruction, it is recommended to administer antibiotics orally for the period of 6 weeks to lower the risk of late infection-related complications (fistula) (ref.[34]).

Hyperbaric oxygen therapy

Hyperbaric oxygen therapy (HBO) was successfully used in treatment of DSWI as an adjunct therapy to standardized treatment. Availability and size of hyperbaric chamber remain a logistic problem, mainly in relation to severe conditions patients are in[36]. Literature describes successful use of HBO in two groups of 55 and 10 patients, respectively, with zero in-hospital mortality[37,38]. On average, between 20-40 cycles of HBO were applied, all patients were generally in good condition and the treatment application was made just before closure of the sternotomy wound or due to soft tissues healing disturbances. DSWI caused by anaerobes is a relevant indication as well.

Comparison of negative wound pressure to conventional therapy of DSWI

Comparison of NPWT efficacy to conventional DSWI therapy has been the focus of many studies. A total of 20 comparative analyses and 6 meta-analyses were found, however, only retrospective non-randomized studies and their meta-analyses are available[27,29,33,39-60]. Moreover, in most of the published studies, obvious heterogeneity in compared patients' and DSWI characteristics was identified. Only in one paper propensity matching to homogenized comparison groups was carried out[33]. Overall, comparative studies confirmed lower risk of therapy failure in NPWT (RR=0.34, 95% CI: 0.19-0.59). In addition, recent publications and meta-analyses implied lower mortality rates in comparison to CT (RR=0.40, 95% CI 0.28-0.57) (ref.[61]). Results of published studies and meta-analyses are depicted in detail in Table 1. Recently, NPWT was recommended as a destination therapy or as a bridge prior to sternotomy wound closure in case of DSWI (Class I, Level of Evidence B) according to EACTS expert consensus statement[62]. Furthermore, NPWT was not found to be more expensive in comparison to CT (2.8 times vs. 2.5 times the cost of uncomplicated cardiac surgery, NS) when calculated within Swedish healthcare system[63]. Another group even demonstrated cost reduction in comparison to CT (31 106 € vs. 24 383 €, 6723 € margin), its results were drawn from Italian healthcare system calculations[64].

Options for sternotomy wound reconstruction after DSWI in the era of NPWT

NPWT is a potent tool for wound bed infection control; nevertheless, sternotomy wound reconstruction is another inevitable step towards DSWI healing. Today, the reconstruction is focused on achievement of chest wall stability because it augments soft tissue healing, usage of local muscle flap advancement, and supports function of the auxiliary respiratory muscles[47,65,66]. Recent studies pointed out better quality of life in such patients in comparison to patients whose residual defect was only covered by a muscle flap, however, survival benefit has not yet been proven[67-69].

Quality and range of sternal lamellae bone loss are the main limitations of chest wall stabilization in DSWI patients. Transsternal or parasternal cerclage insertion and potentially parasternal binding (Robicsek and his modification) require preservation of major portions of sternal lamellae[70]. Furthermore, it is necessary to loosen granulation tissue adhesions in between sternal lamellae and anterior mediastinum, bearing certain risk of bypass graft or heart damage[47,66]. In the last ten years, efforts to lower this risk led to preferential use of plate osteosynthesis and parasternal fixation-enabling systems[66]. In a major published group (92 patients), in which stable plate osteosynthesis was used (Titanium Sternal Fixation System™, Synthes, Switzerland) for sternotomy wound reconstruction after DSWI, only 9.8% had their plates removed due to late-onset infection (fistulae). The removal had little to no impact on their chest wall stability[47,65]. Recently published retrospective comparison of sternotomy wound stabilization by titanium plates (20 patients) versus coverage by a muscle flap without sternal stabilization (22 patients) proved that the group of patients who underwent the plate osteosynthesis had shorter actual reconstruction procedure duration (138.8±25.8 vs. 184.3±75.9 h, P=0.009) as well as shorter in-hospital stay after the reconstruction had been done (18.1±20.6 vs. 38.9±39.3 days, P=0.025). Concerning one-year mortality, there was hardly any significant difference between the two groups (15 vs. 27.2%, P=0.187). According to questionnaire SF-12, patients with stable plating indicated significantly better quality of life (42.8±8.6 vs. 29.5±10.7 points, P=0.034) (ref.[68]). Moreover, another retrospective study has also proven significantly lower risk of DSWI recurrence in patients with stable plating (36 patients) in comparison with those who had their defect covered by a muscle flap only (26 patients) (8.9 vs. 40%, P=0.02). Shorter in-hospital stay (22.4±3.1 vs. 25.6±3.1 days, P<0.05) was recorded in patients after plating but with insignificant difference in hospital mortality (11.1 vs. 19.2%, P=0.47) between both groups[68]. An outer parasternal fixation system (Atraumatic Sternum Closure System™; KS Handelsvertretung Produktinovation, Germany) was successfully implanted in 16 DSWI patients. Its application is simple and needless of extensive pectoral muscle deattachment and sub-sternal dissection, however similarly to wire cerclage, the major sternal lamellae preservation is required[71].

On the other hand, major residual sternal bone loss or loss of adjacent ribs still possesses a challenge after DSWI treatment, even in the plating era[66]. The bone residue does not allow for either sufficient anchoring for the plates or there is a large bone tissue gap. Shear forces may loosen screws and threaten stability[47,66]. A conventional surgical approach to manage the large residual bone defect leaves the sternotomy wound unstable and employs the greater omentum or pedicled muscle flaps to fill in any dead spaces[67,70]. However, this approach resulted in sternal instability and flap-related morbidity even when wounds were well-healed[66,67]. Nowadays, autograft or homograft bone replacement and its anchoring with titanium plates is an option for major residual bone defects. Bicortical autologous bone iliac crest graft or fibula graft can be used for smaller defects, cadaverous sternum, potentially sternocostal homografts are, on the other hand, used for filling-in of major defects[72-75]. The first sternal homograft was used by Marulli after sternal chondrosarcoma resection[76], procedure has progressively been adopted for patients with extensive bone loss due to DSWI (ref.[75,76]). Published results show that complete chest stability after bone homograft implantation was achieved in 90% patients, moreover, a scintigraphy study showed increased accumulation of radiopharmaceuticals in implanted homografts suggesting homograft's conversion to active tissue[66,77]. Bone

Table 1. Analyses and meta-analyse of comparison NPWT with CT.

Follow-up	Patients‘ cohort	End-points	Results	Ref.
Retrospective	11 pts NPWT vs. 9 pts closed irrigation	In-hospital stay, therapy failure	NPWT linked to shorter in-hospital stay (15 vs. 40.5 days, *P*=0.02) and lower therapy failure (0 vs. 5%, *P*=0.03) than closed irrigation	27
Retrospective	31 pts NPWT vs. 29 pts closed irrigation	Therapy failure, in-hospital stay and mortality	NPWT group had a lower risk of therapy failure (52 vs. 16%, *P*<0.05) and in-hospital stay (22 vs. 26 days, *P*<0.05), with comparable in-hospital mortality (6.9 vs. 6.6%, NS) to closed irrigation	39
Retrospective	22 pts NPWT vs. 22 closed irrigation	Therapy failure, in-hospital stay and mortality	NPWT group had shorter overall length of therapy (17.2±5.8 vs. 22.9±10.8 days, *P*=0.01) and in-hospital stay (27.9±6.6 vs. 33.0±11.0 days, *P*=0.03), with comparable mortality (5 vs. 5%, NS) to closed irrigation	40
Retrospective	17 pts NPWT vs. 18 pts muscle flap covering	Therapy failure, number of dressing changes, in-hospital stay and mortality	NPWT associated with shorter length of therapy (6.2 vs. 8.5 days, *P*<0,05), lower number of dressing changes (3±2.5 vs. 17±8.6, *P*<0.01), and comparable in-hospital mortality (11 vs. 6%, NS)	41
Retrospective	27 pts NPWT vs. 13 pts closed irrigation	Therapy failure, in-hospital mortality, and cost of therapy	NPWT linked to lower therapeutic failure rate (15 vs. 30.7%, *P*<0.05), in-hospital mortality (7.5% vs. 18.5%, *P*<0.05) and overall cost of therapy (16 400 vs. 20 000 USD, NS) compared with closed irrigation	42
Retrospective	35 pts NPWT vs. 33 pts muscle flap covering	Length to achieve sterile wound, length of therapy, in-hospital stay, and 1-year survival	NPWT led to faster bacterial decontamination of wounds (16 vs. 26 days, *P*<0.01), shorter length of therapy (21 vs. 28 days, *P*<0.01) and in-hospital stay (25 vs. 34 days, *P*<0.01) and better 1-year survival (97.1 vs. 74.7%, *P*<0.05) compared with open packing	43
Retrospective	61 pts NPWT vs. 40 closed irrigation/muscle flap covering	Therapy failure, 1- and 5-year mortality	NPWT had lower risk of therapy failure (0 vs.15%, *P*<0.01), 90-day mortality (0 vs. 15%, *P*<0.01), and 1- and 5-year survival (93 vs. 82%, 83 vs. 59%, *P*<0.05) compared to conventional therapy	44
Retrospective	38 pts NPWT vs. 17 muscle flaps covering	In-hospital stay and in-hospital mortality, quality of life	NPWT led to shorter in-hospital stay (51.5±20.8 vs. 70.7±28.8 days, *P*<0.05), non-significantly lower in-hospital mortality (5.3 vs 11.8, NS) and better quality of life based on questionnaire SF-36 compared with sternectomy and flap	40
Retrospective	29 pts NPWT vs. 34 pts closed irrigation	Therapy failure, in-hospital, and 1-year mortality	NPWT decreased primary therapy failure (27.6 vs. 58.9%, *P*<0.05), with comparable 30-day (3.5 vs. 2.9%, NS) and 1-year mortality (31.0 vs. 23.5%, NS) to closed irrigation	46
Retrospective	125 pts NPWT vs. 24 pts muscle flap covering	In-hospital mortality and 1-,5-, and 10 years survival	Lower mortality in NPWT group (4.8 vs. 14.1%, *P*=0.01), but insignificantly better 1-, 5-, and 10-year survival (92.8 vs. 83.0%, 89.8 vs. 76.4%, 88.0 vs. 61.3%, NS)	47
Retrospective	69 pts NPWT vs. 49 closed irrigation	Therapy failure, in-hospital stay and mortality	NPWT associated with lower therapeutic failure (2.9% vs.18.3% *P*<0.05) and in-hospital mortality (5.8% vs. 24.5% *P*<0.05), but comparable in-hospital stay (38 vs. 41 days, NS) with closed irrigation	48
Retrospective	38 pts with NPWT vs. 28 pts closed irrigation	Therapy failure, in-hospital stay, in-hospital, and 1-year mortality	NPWT had lower failure of primary therapy (5.8 vs. 39.2%, *P*<0.05), ICU stay (209.6±33.3 vs. 516.1±449.5 h, *P*<0.01), and in-hospital (5.8 vs. 21.4%, *P*<0.05) and 1-year mortality (14.7 vs 39.2%, *P*<0.05), but comparable in-hospital stay (40.2±16.3 vs. 48.8±29.2, NS) with closed irrigation.	49

Table 1. *Continued*

Follow-up	Patients' cohort	End-points	Results	Ref.
Retrospective	74 pts NPWT vs. 83 pts closed irrigation	Therapy failure, in-hospital stay and mortality	NPWT group with lower risk of therapy failure (1.4 vs. 16.9%, *P*<0.001), shorter in-hospital stay (23.3±9 vs. 3.0.5±3, *P*<0.05), and lower in-hospital mortality (1.4 vs. 3.6 %, *P*<0.05) compared with closed irrigation	50
Retrospective	82 pts NPWT vs. 38 closed irrigation	In-hospital stay and mortality	NPWT patients had shorter in-hospital stay (45.6 ± 18.5 vs. 55.2 ± 23.6 days *P*<0.05), and lower in-hospital mortality (14.6 vs. 32.4 %, *P*<0.05)	51
Retrospective	89 pts NPWT vs. 24 muscle flaps covering	In-ICU and hospital stay and mortality	NPWT led to shorter ICU stay (6.8±14.4 vs. 18.5±21.0 days *P*<0.01), in-hospital stay (74.4±61.2 vs. 69.1±62.7 days, *P*<0.01), and lower in-hospital mortality (12.4 vs. 41.7%, *P*<0.01)	52
Retrospective	47 pts NPWT vs. 43 pts closed irrigation	Therapy failure, in-hospital stay and 1-, 3 years mortality	NPWT had insignificantly lower rate of primary therapy failure (2.1% vs. 4.7%, NS) and shorter in-hospital stay (18±9 vs. 24±10 days, NS), 90-day mortality significantly lower (8.5 vs. 23.2%, *P*<0.05) and better 1-, and 3-year survival (91.5% vs.76.7%, *P*<0.05, 87.2 vs. 69.8%, *P*<0.05)	53
Retrospective	326 pts NPWT vs. 198 pts closed irrigation/muscle flap covering	Therapy failure, in-hospital mortality	NPWT was associated with lower primary therapy failure (8.5% vs. 34% *P*<0.001), and in-hospital mortality (3.6% vs. 10%, *P*<0.05)	54
Retrospective	64 pts NPWT vs. 66 pts closed irrigation	Therapy failure, in-hospital mortality, and 10-year survival	NPWT had lower rate of primary therapy failure (6% vs. 21%, *P*<0.01), but comparable 30-day (3.1% vs. 0%, NS) mortality and no long-term survival benefit of NPWT	55
Retrospective	20 pts NPWT vs. 23 pts closed irrigation	Therapy failure, in-hospital and 1-year mortality	NPWT was associated with lower primary therapy failure (5% vs. 34.8%, *P*=0.02), the 30-day mortality was not significantly different between groups (4% vs. 0%, NS) and the same was true for 1-year mortality (17% vs. 0%, NS).	56
Retrospective	22 pts NPWT vs. 22 pts closed irrigation	In-hospital mortality, independent predictors of survival	NPWT carried significant lower in-hospital mortality (5 vs. 38%, *P*=0.021), NPWT was found to be independent predictor of survival (OR 0.062; *P*=0.041) as well as usage of muscle flap for sternotomy wound closure (OR 0.022; *P*=0.048)	33
Meta-analysis	12 papers focused on comparison of NPWT with CT	Therapy failure, in-hospital stay and mortality	NPWT was associated with lower primary therapy failure, shorter in-hospital stay, and lower in-hospital and 1-year mortality	29
Meta-analysis	13 papers focused on comparison of NPWT with CT	Therapy failure, in-hospital stay and mortality	NPWT seemed to be effective at high-risk DSWI patients, but with weak evidence for routine first-line application in DSWI	57
Meta-analysis	15 papers focused on comparison of NPWT with CT	Therapy failure, in-hospital stay and mortality	NPWT is associated with lower therapeutic failure, and in-hospital mortality. Routinely applied as first-line treatment in 35% of German heart centres	58
Meta-analysis	6 papers focused on comparison of NPWT with CT	Therapy failure, in-hospital stay and mortality	NPWT proved to have shorter in-hospital stay and lower mortality	59
Meta-analysis	7 papers focused on comparison of NPWT with CT	Therapy failure, length of therapy, and in-hospital stay	NPWT was associated with lower risk of primary therapy failure, shorter in-ICU stay, and comparable in-hospital stay	60
Meta-analysis	22 non-randomized studies focused on comparison of NPWT (2467 pts) with CT (2233 pts)	Mortality, risk of therapy failure, in-hospital stay	NPWT was associated with lower mortality rate (RR 0.4, 95% CI 0.28-0.57), lower rate of primary therapy failure (RR 0.34, 95% CI 0.19-0.59), but no difference in the length of in-hospital stay (RR -2.25, 95% CI -7.52-3.02) in comparison to CT	61

allograft usage for transplantation is restricted under local governments and European Association of Tissue Banks[78]. Recently a multidirectional thoracic wall stabilization system (STRATOS™, MedXpert GmbH, Germany) has become available to help repair extensive chest wall defects after tumor resection[79]. The system enables bone defect bridging without needing it to be filled in with bone auto-, homograft, however, the experience of resolving DSWI related sternal defects is, for now, limited[80].

Complication of DSWI treatment

Severe bleeding during DSWI therapy is a life-threatening complication. Damage to the right ventricular free wall or to bypasses, less frequently to major vessels, ranks among distinctive bleeding causes. Causes of bleeding might be due to erosion that occurred due to infectious processes; however, mostly mechanical injury plays a part[81]. There is a risk of either direct injury due to sternal lamella or due to pull of adhesion between the right ventricle and sternum when rapid intrathoracic pressure changes come (cough) (ref.[82]). The incidence of severe bleeding ranges between 2-14.8% in CT and increases with primary muscle flap covering rather than with closed irrigation[81,83]. Recent data showed a 2-6% risk of this complication during NPWT with the mortality rate varying between 19-55% (ref.[83-85]). Meticulous covering of mediastinal structures with use of non-adhesive interface materials is a vital part of NPWT application in DSWI as well as cough prevention and upper limb movement restriction[29,84]. Some centres recommended routine release of adhesions in between the right ventricle and left sternal lamella as a part of NPWT application protocol[85,86]. Polyurethane perforated disc (20x10x0.2 cm) has been recently tested to shield the mediastinum from direct contact with drainage sponge as well as sternal lamellae. Thanks to micro-apertures, mediastinal drainage is not limited by disc[87.] It led to decrease in NPWT duration (3.1±0.4 vs. 5.4±0.6 dressings, $P<0.01$), faster decline in CRP levels ($P<0.05$) and smaller amount of epicardial petechial haemorrhages (2.3±2.2 vs. 5.4±3.6, $P<0.05$) in comparison with usage of layered non-adhesive interface dressing[88,89]. Data from long-term follow-up suggest that the risk of late infection complications (fistulae) ranged between 8-12% and became almost equivalent to those seen in NPWT and CT (ref.[29,49,65,90,91]). Fistula-related management goes hand in hand with further need for in/out-patient care and cost increase, and according to one study such patients have decreased long-term survival rates[90.] Debridement plays a crucial role in the drop of early (failure of DSWI primary therapy failure) and late recurrence (fistula) of DSWI (ref.[66,91]). During NPWT, debridement is done repeatedly, and granulation tissue formation is strongly stimulated by negative pressure. On the other hand, improper debridement may lead to granulation tissue overlapping the infected or hypo-vital skeleton parts which can be manifested as infection recurrence, particularly coupled with biofilm-producing agents like Coagulase-negative Staphylococci and Pseudomonas[35,90].

CONCLUSION

Robicsek postulated vital DSWI management principles almost 20 years ago including: controlling the infectious process as quickly as possible, proper debridement, effective wound drainage, and the achievement of thoracic wall stability after sternotomy wound reconstruction[70]. However, single approach to the treatment strategy of DSWI has not yet been generally accepted. The possibility to perform debridement repeatedly, unlimited drainage capacity, and strong stimulation of granulation tissue formation within NPWT, together with modern tools of sternal stabilization and bone-/soft tissue reconstruction, draw us closer to Robicsek‘s postulates. Undoubtedly, DSWI will continue to be a major complication of cardiac surgery. On the other hand, proper and brief infection control preventing MOF development, and stable sternotomy wound reconstruction afterwards are able to provide near-to-comparable long-term outcomes of DSWI patients with those who have had an uncomplicated postoperative course after cardiac surgery.

ABBREVIATIONS

CT, conventional therapy; EACTS, European Association for Cardio-Thoracic Surgery; DSWI, deep sternal wound infection; ICU, intensive care unit; MRSA, methicillin-resistant Staphylococcus aureus; MOF, multiple organ failure; NPWT, negative pressure wound therapy; NS, statistically non-significant; OR, odds ratio; RR, risk ration.

Search strategy and selection criteria

Data for this article were identified by searches of PubMed using the mesh words “DSWI treatment”, “conventional therapy”, “open packing”, “closed irrigation”, “muscle flap covering”, “negative pressure wound therapy”, and “VAC therapy”. Preference was given to publications presenting larger cohorts and using sound methodology. Citations from respectable journals were given special weight. English and German language papers were reviewed.

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